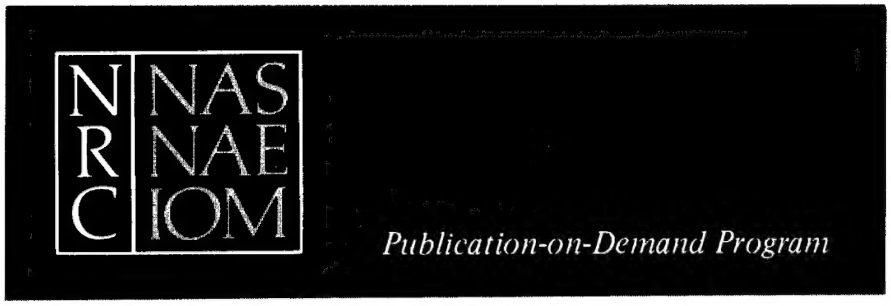

Manufacturing Technology

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MANUFACTURING TECHNOLOGY

MANUFACTURING TECHNOLOGY:

CORNERSTONE OF A RENEWED DEFENSE INDUSTRIAL BASE

Committee on the Role of the
Manufacturing Technology Program
in the Defense Industrial Base

Manufacturing Studies Board

Commission on Engineering and
Technical Systems

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PREFACE

The Manufacturing Technology (ManTech) program of the Department of Defense (DOD) is intended to improve the productivity and responsiveness of the U.S. defense industrial base by funding the development of manufacturing technologies. The DOD program, by providing seed funding for development of process and equipment technology, permits contractors to upgrade their manufacturing capabilities. Ultimately, the program aims to produce high-quality weapon systems with shorter lead times and reduced acquisition costs.

The ManTech program has recently been criticized, and its continuance has been in doubt. In the late 1970s and early 1980s, the program was projected to grow at a rapid pace. By 1986, however, the Army ManTech program has been largely dismantled and the Navy program has been reduced and redirected. The Air Force program, while remaining stable, has not achieved its planned growth.

The Army, Navy, Air Force, and National Science Foundation asked the National Research Council, through its Manufacturing Studies Board, to form a committee to answer fundamental questions being asked about the need for and directions of the program. The committee was directed to examine the basic principles underlying the program and recommend the appropriate role and mechanisms for DOD to encourage the development of manufacturing technology. The National Science Foundation's interest in the topic derives from its experience in developing methodology for evaluating federal programs.

The Manufacturing Studies Board accordingly set up the Committee on the Role of the Manufacturing Technology Program in the Defense Industrial Base. It comprises 20 members (12 original members, 8 who were added for this report) with experience in advanced manufacturing

technology, military procurement, financial accounting, manufacturing management, and manufacturing strategic planning.

As is true of all Research Council committees, the Committee on the Role of the Manufacturing Technology Program in the Defense Industrial Base was selected to balance the "biases" of its members regarding the subject of study. In this case, the committee had roughly equal numbers of ManTech supporters, persons skeptical of the program, and persons who had not yet formed an opinion of the merits of ManTech. Through its research and deliberations, the committee achieved a convergence of opinion, which is reflected in this consensus report.

The committee divided its work into two phases. This report summarizes its conclusions from phase II. In its phase I report, The Role of the Department of Defense in Supporting Manufacturing Technology Development, the committee examined what role, if any, DOD should have in supporting the development of manufacturing technology. The committee concluded that such support is critical to the nation's defense, and that direct funding via the ManTech program can provide essential benefits that other methods cannot.

During phase II, the committee directed its efforts to determining how DOD should manage its investments in manufacturing technology development. The committee examined the experience of the ManTech program and formulated its answer in relation to the program.

Throughout the report, the committee refers to the processes and equipment used in production as manufacturing technology (using lower case m and t). The DOD program is referred to as either the Manufacturing Technology program or ManTech (using upper case M and T).

ACKNOWLEDGMENTS

The Committee on the Role of the Manufacturing Technology Program in the Defense Industrial Base is responsible for organizing and conducting the research and writing the findings of this study. Our work would not have been possible, however, without the contributions of the Manufacturing Studies Board staff who facilitated our work: executive director George Kuper, staff officers Carolyn Castore and Janice Greene, and administrative assistants Lucy Fusco and Michael Resnick. We are grateful to the General Accounting Office for allowing Ms. Castore to work on this project through an Interagency Personnel Agreement.

We wish to thank the four peer reviewers--Norman Augustine, Jacques Gansler, David Mowery, and William Spurgeon. Their thoughtful comments on our draft report enabled us to fine-tune its substance and presentation.

Thanks are owed to McKinsey and Company for assistance with the computer analysis of ManTech projects and to Gerald Susman of the Pennsylvania State University for conducting a case study of a ManTech project. In addition, the many people who spoke freely with the committee provided invaluable information.

Finally, we wish to thank our liaisons in the federal government for their assistance: Assistant Secretary of Defense for Production and Logistics Robert Costello; Deputy Assistant Secretary John Mittino; Richard Donnelly, Charles Kimzey, and Lloyd Lehn of the Office of the Assistant Secretary of Defense for Production and Logistics; Robert Fear and Fred Michel of the Army Materiel Command; John McInnis and Steven Linder, Office of the Assistant Secretary of the Navy for Shipbuilding and Logistics; Gary Denman, Vincent Russo, and Nathan Tupper of the Air Force Materials Laboratory; Daniel Gearing and Donald O'Brien,

Defense Logistics Agency; and George Hazelrigg of the National Science Foundation. We particularly appreciate Charles Kimzey's coordination of the Defense Department's participation in this study.

This report was greatly enhanced by the willing and open exchange of information by the officials of the Manufacturing Technology program.

Wickham Skinner
Chairman

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SUMMARY

The U.S. defense industrial base is deteriorating. Long lead times to procure weapon systems, high costs, uncertain quality, and dependence on procurement of electronic components from other countries are symptoms of a decline in the capability of the U.S. defense industrial base.

A primary cause of this decline is the failure of the Department of Defense (DOD) and its contractors in the U.S. defense industry to invest sufficiently in manufacturing technology. The lack of investment reflects DOD's history of concentrating its resources and attention on product technology rather than process technology.

As we described in our initial report, The Role of the Department of Defense in Supporting Manufacturing Technology Development, existing procurement policies and regulations do not provide sufficient investment incentives to contractors. Therefore, direct funding for some manufacturing technology development will have to be provided by DOD. Specifically, direct DOD funding should support process technology that:

- requires long lead times for development,
- is too risky--either technically or economically--for contractors to undertake on their own,
- is critical to meeting unique defense requirements, and
- is applicable to more than one supplier or weapon system.

Only one program in the Department of Defense, the Manufacturing Technology (ManTech) program, focuses on the long-term basic strength of manufacturing. Compared to many other DOD programs, ManTech is small. At its highest

level of funding--$204 million in fiscal 1982--ManTech represented just over 0.1 percent of DOD's procurement budget. Its share has been shrinking rapidly since then. In fiscal 1987, funding had dropped to $124 million. The current ManTech program is vital and needs to be strengthened. Our suggestions for improvement should not be used out of context to weaken it further. Unless the trend of shrinking funding and diminished influence is reversed, the country will soon lose not only the ManTech program, but also the primary source of direct federal investment in defense manufacturing technology development.

The ManTech program's potential leverage on defense manufacturing is enormous. Its impact has been sharply limited over the past decade, however, by the lack of a coherent DOD policy for manufacturing technology and the lack of attention to the role of ManTech in meeting DOD's strategic goals. If this strategic link were provided in the future, the improved manufacturing capability from a strengthened and newly effective ManTech program could:

- provide significantly more defense materiel for the same expenditure,
- accelerate the completion of new weapon systems by substantially decreasing the cycle times for development and production,
- create technologies that enable defense manufacturers to provide more sophisticated performance features in new weapon systems, and
- reduce the dependence of the U.S. defense industrial base on the availability of certain key components or materiel from other countries.

The current ManTech program, however, under pressure to respond to operational needs at lower levels, has tended to fund small projects with narrow objectives. The program has emphasized projects with demonstrable short-term cost reductions because many within DOD and the Congress view cost reduction as the most valid measure of program effectiveness. This narrow view has driven the ManTech program toward short-range, low-risk projects rather than the major, strategic, and innovative objectives for which the program is most needed.

The committee concluded that a redesigned, well-defined, and well-directed DOD ManTech program can produce major improvements in the capability and responsiveness of the defense industrial base. To gain the benefits of a strong program, we recommend that:

- the Secretary of Defense establish a clear mission for the ManTech program that links to DOD strategic goals and future weapon systems requirements;
- the Office of the Secretary of Defense (OSD) and the services work together to define priorities, so that projects will respond to defense needs;
- the OSD maintain some centralized control to coordinate the services in a unified program;
- the services, which already have the technical expertise and connection with the mission, retain control of project definition and management; and
- within each service, the program have centralized control in order to avoid fragmentation.

A well-structured ManTech program, perhaps given a new name to emphasize these fundamental changes, should become a major part of a needed focus within DOD on manufacturing. Such a program can provide leverage by conveying DOD's intention to support meaningful progress in manufacturing capability and by communicating DOD's priorities to contractors.

While a redesigned ManTech program is needed, it cannot be the entirety of DOD's manufacturing policy. A strengthened ManTech program can, however, become the cornerstone of a comprehensive DOD policy to enhance manufacturing capabilities.

1 THE COMPETITION FOR MANUFACTURING SUPREMACY

This nation's defense is threatened by a weakening industrial base. The current problems of weapons with uneven quality and reliability, long delivery cycles, dependence on foreign suppliers for critical components, and, most visibly, high costs are all symptoms of the deteriorating manufacturing capabilities of U.S. suppliers.

In attempting to meet the demanding and increasingly sophisticated performance requirements of weapon systems, the country is spending more and producing less. The Department of Defense (DOD) has sought innovation in the design and performance of weapon systems while largely ignoring the production processes needed to make those systems. As a result, obsolete manufacturing processes are being used to build ever more sophisticated weapon systems, leading to sharply rising costs of weapon systems, shrinking numbers of units affordable to DOD, and unreliable performance of those that are acquired.

More serious has been the declining competitive strength of the defense industrial base. The steel, machine tool, and shipbuilding industries--all essential to winning World War II--have severely declined in the face of the current global economic competition. Further, the United States is gradually losing its competitive edge in other industries that are currently vital to defense. Even high-technology industries such as electronics, semiconductors, and aerospace are challenged.[1] Unless the defense industrial base renews its focus on innovation in manufacturing processes and equipment, more industries will fall further behind in the competition for manufacturing supremacy.

THE ROLE OF DOD IN THAT COMPETITION

The defense industrial base ranges across a broad spectrum of industries, and comprises approximately 30,000 prime contractors and 100,000 vendors and suppliers.[2] While the entire U.S. industrial base--including producers of commercial as well as defense products--faces many common manufacturing problems, this report focuses on the segment that manufactures materiel purchased by DOD.

The Department of Defense has a critical need and responsibility to address the manufacturing technology problems that arise within the defense industrial base. DOD can spur major improvements in the health and performance of industry by investing in longer-range, high-risk,[3] innovative projects that, if successful, would yield major advances in manufacturing technology in areas of strategic importance.

Neither DOD nor defense contractors have been investing adequately in manufacturing process and equipment technology.[4] The defense industrial base lacks incentives for such investment under current procurement procedures, and many federal policymakers concerned with defense do not recognize the need to invest in advanced manufacturing technology. Without adequate manufacturing processes, even skilled and motivated workers and managers can neither turn out high-quality products nor meet demanding schedules.

The importance of production technology becomes clear during wartime, when the objective is to produce the largest number of acceptable quality weapons as quickly as possible. During peacetime, the value of production technology has been less obvious. Even in peacetime, however, the United States needs to get significantly greater value for its defense expenditures. Leading-edge manufacturing technology offers an opportunity to improve the availability, affordability, and performance of weapon systems.

THE NEED FOR THE MANTECH PROGRAM

Within DOD, the Manufacturing Technology (ManTech) program[5] has been the primary program for upgrading the long-term manufacturing technology available to the U.S. defense industrial base.[6] It supports the development of innovative manufacturing technologies by defense contractors.

The committee's phase I report[7] argued that research and development in manufacturing equipment and process technology are vital to the welfare of the nation. Further, because government procurement policies and regulations have disincentives that deter contractors from investing in developing innovative manufacturing technology,[8] DOD needs to take an active role to promote the development of manufacturing technology for weapon systems. The report also recommended that DOD directly fund manufacturing technology development, via the ManTech program, in areas that:

- can solve generic problems,
- require long lead times,
- have the potential for substantial improvements in the manufacturing system, and
- are beyond the normal risk of business.

The committee concluded, however, that significant changes were needed to improve the effectiveness of the ManTech program. Thus, phase II of the study focused on developing recommendations for enhancing the program.

A NEW MANTECH PROGRAM

The ManTech program we recommend differs substantially from the DOD program of the past decade. Basic changes in the ManTech program, initiated by the Office of the Secretary of Defense (OSD), can make it an effective part of the competition for manufacturing supremacy. Because of differences among the three services' programs, the services will require different amounts of change. The present Air Force program comes closest to the program we recommend. The Defense Logistics Agency's ManTech program is too new to have been included in our analysis, but our recommendations apply to them as well as to the services.

As we will describe in the next three chapters, an effective ManTech program must begin with the selection by OSD, in cooperation with the services, of the critical manufacturing capabilities on which to focus attention and funding. ManTech program managers can then translate DOD's strategic needs into specific technologies needed to support future generations of weapon systems. OSD should also be responsible for assessing the plans (but not the individual projects) of the services and allocating funds for ManTech activities.

The ManTech program should strive to support innovative generic process technologies that are required for future weapon systems. To convey to the defense community the long-term, strategic policy orientation of the program, a new name, such as the Advanced Manufacturing Technology program, may be required.

A primary outcome of the program should be to demonstrate the feasibility of new, critical process technologies that will permit future production of affordable, high-performance products. In the long run, lower costs are also likely to occur. However, because of the time lags between project initiation and ultimate operation, the impact of product design change decisions, and inadequate accounting systems, such cost reductions will be difficult to document.

The new ManTech program cannot address all of the manufacturing problems faced by the 130,000 DOD suppliers. A much more comprehensive DOD manufacturing policy is required to accomplish not only longer-range advances in manufacturing technology but also widespread application of leading-edge technology and improvement of existing production facilities. The new ManTech program can provide only the first part of such a policy: to develop new manufacturing capability.

Many of the low-risk, less generic projects that are currently funded by the ManTech program are worthwhile but outside the scope of the new ManTech program. Even with an extremely successful new ManTech program, weapon systems will continue to face short-run manufacturing problems when entering production. Projects that address such problems should be directed by individual weapon systems program managers.

The new ManTech program will get maximum leverage from its investments by:

- focusing on generic issues in which the potential impact across contractors is high, and
- using the funds as seed money to stimulate further investment by defense contractors.

NOTES

1. According to The President's Commission on Industrial Competitiveness, the United States has lost market share in 7 out of 10 high-technology sectors. (Global Competition: The New Reality, January 1985, p. 13.)

2. Information obtained from Richard Donnelly, Director, Industrial Resources, Office of the Under Secretary of Defense (Research and Engineering).

3. High-risk projects involve economic or technical risk. Companies are less likely to support a project that requires a major investment in time, expertise, and equipment if technical success is uncertain. If the costs of research and development cannot be recovered within a specified time, then investment is minimal--if it occurs at all.

4. Japan, France, West Germany, and Great Britain have had higher capital investment as a percentage of output in manufacturing than the United States, at least since 1965. See, for example, Manufacturing Studies Board, Toward a New Era in U.S. Manufacturing (Washington, D.C.: National Academy Press, 1986), p. 16.

5. As in our initial report, the processes and equipment used in production are referred to as manufacturing technology (with lower case m and t). The DOD program studied is referred to as the Manufacturing Technology or ManTech program (with upper case M and T).

6. Independent research and development (IR&D), materials R&D, Title III, and facilities grants all include some expenditures for manufacturing technology. Only the ManTech program has the upgrading of manufacturing technology as its raison d'etre.

7. National Research Council, Manufacturing Studies Board, The Role of the Department of Defense in Supporting Manufacturing Technology Development (Washington, D.C.: National Academy Press, 1986).

8. The recent change in law to allow multi-year contracts under some circumstances increases the incentive to invest in manufacturing technology. The disincentive of renegotiating contracts to reduce profits that result from increased efficiency, however, still applies to most contracts. Further, the continuing separation of design from production contracts severely limits opportunities to design products that take advantage of advanced manufacturing technology. On balance, the disincentives still overwhelm the incentives to invest in process technology.

2 UNDERESTIMATING THE IMPORTANCE OF MANTECH LIMITS ITS IMPACT

The existing Manufacturing Technology program could have been the strong program advocated in the previous chapter. Its accomplishments have fallen short of DOD's needs, however, because the program's direction was not sufficiently integrated into overall DOD strategy. In the few instances when leadership was present and coordinated groups of ManTech projects were aimed at significant future performance requirements, the program succeeded in greatly improving the production of weapon systems.

Since this study began, major reductions in the Army and Navy ManTech programs have left the Air Force as the only service with a meaningful ManTech program. The Army budget, formerly the largest of the three, has been reduced to $16 million and supports only government-owned arsenals, depots, and ammunition plants. The Navy ManTech budget has continued its historical pattern of extreme fluctuations. In 1987, its budget was reduced by $20 million to $29 million. Despite planned growth, the Air Force ManTech budget has remained constant. These declines in ManTech support and funding have made more urgent the needs for adequate investment in manufacturing technology and broad systemic changes in the program.

MANTECH: A COLLECTION OF SMALL, LOW-RISK PROJECTS

To determine the strategy implicit in the current ManTech program, the committee analyzed the 238 multi-year projects that received funding in 1985 or 1986 and that had total budgets of at least $1 million. These projects represented a spectrum of projects begun between the late 1970s and 1986, equaling 40 percent of all ManTech

projects funded during 1985 and 1986. They had a combined total budget exceeding $800 million over the duration of the projects.

Our project analysis, described in Appendix A, led to several broad conclusions:

- The program spread small amounts of funds across many diverse projects.
- The projects, particularly in the Army and Navy, were largely unrelated and did not comprise coordinated thrusts focused on particular technological innovations.
- The projects' objectives were severely limited in scope, risk, and technical challenge.
- As a result, the program's overall impact has been modest.

We believe that the $1.2 billion expended by the ManTech program during 1980-1986 could have produced major advances in manufacturing technology. Indeed, the small portion of ManTech funds spent on technically challenging, related sets of projects has produced a far greater aggregate impact than the much greater amount spent on unrelated projects of limited scope.

The Superlative Few

A few of the projects in the ManTech program were designed to create technological innovations for future weapon systems. In three areas--electronic materials, infrared sensing materials, and composites--related sets of ambitious projects were directed at process developments to improve the material's performance and increase yield and quality. The Air Force program offers other examples of well-directed technological thrusts that yielded new products and product features, while reducing manufacturing cost and increasing quality:

- new processes for unusual materials substantially increased the performance of jet engines,
- flexible machining of short runs of parts,
- noncontact gauging and testing technologies to improve the in-process quality control of a variety of products, and
- production of new types of aircraft made possible by advances in the production of composite structures.

The Integrated Computer-Aided Manufacturing (ICAM) program was one of the largest sets of related Air Force ManTech projects. The ICAM program mobilized teams of defense contractors and universities to attack several dozen aspects--including management as well as technology--of a highly significant problem. Not all projects were ultimately incorporated into the solution of the problem; those that were technically ready at a cutoff date were combined in a demonstration of an integrated sheet metal manufacturing center.

The advances achieved in these process technologies will play a part in weapon system production for years to come. Because of their breadth and importance, successful sets of ManTech projects in areas such as electronics, composites, and computer-integrated manufacturing will continue to stimulate further advances.

In each of these innovations, the following circumstances helped shape the investment and were critical to its success:

1. Weapon system program managers recognized that advances in manufacturing technology were indispensable to the feasibility and ultimate performance of the weapon system.
2. Funding for product development was closely paralleled by funding for process development.
3. No commercial application was apparent to stimulate development of the enabling manufacturing technologies quickly enough to meet the defense needs of the country.

These successful examples provide a model that, if extended to a broader set of technologies, would constitute a highly effective ManTech program.

The Limitations of Investing Without a Strategy

In contrast to these few high-impact areas, most of the 238 ManTech projects we analyzed showed the following general trends:

- Purpose: More projects (40 percent) had cost reduction as the primary purpose than any other single purpose. In addition, cost reduction was made a secondary objective for numerous other projects.

- Materials: Many of the projects (36 percent) were focused on metals. Emerging technologies for processing new materials, such as ceramics and composites, received much less attention.
- Breadth: More than half the projects were directed at a narrow technical objective, a single product, and, particularly in the Army, a single facility.
- Technology: The Army expended more than 30 percent of its funds on projects aimed at the inspection process, while the Navy and Air Force divided their funds largely among other processes, such as machining, assembly, and forming.

These characteristics add up to a DOD ManTech program concentrated on the near-term needs of DOD, with narrowly focused, unrelated projects. Only the Air Force program had discernible groups of projects focused on achieving particular goals. The wide variety of technical projects undertaken by the ManTech program testifies to the number and variety of technologies incorporated in current weapon systems. However, without a strategy that targets important technologies, the program's resources have not been directed toward areas of maximum impact.

THE MANTECH PROGRAM NEEDS TOP MANAGEMENT ATTENTION

Managing ManTech--that is, identifying technical needs, setting priorities, selecting projects, allocating funds, monitoring progress, and communicating results--is a complex process involving many levels of authority and many different units within the services and DOD. The dispersion of projects indicated by our analysis suggests that these strategic choices have not been made.

To get further insight into the management of the program, we interviewed officials at 22 defense contracting companies, 10 ManTech program managers and officials in the Office of the Secretary of Defense, 3 staff members of the House of Representatives Defense Appropriations Subcommittee, 11 senior officials--including career civilian, military, and political--in OSD and the services, and 5 former senior officials of DOD. These interviews confirmed that the lack of high-level policy direction, and the relatively low priority given to manufacturing technology within DOD, had caused the fundamental problems of the program.

Common Myths

Our interviews pointed to four myths about manufacturing technology and the defense industrial base that are insupportable but are still widely held. Widespread belief in these myths has reduced support for and understanding of the ManTech program.

Myth #1. The defense industrial base, if forced to compete, will develop and invest in state-of-the-art manufacturing technology.

Myth #2. Once excellent products have been designed and developed, excellent processes for producing them will be routinely available.

Myth #3. Investment in manufacturing technology is worthwhile only if it causes verifiable short-term cost reductions.

Myth #4. "Overhead" is bad; it connotes inefficiency at best and virtual fraud at worst.

The first myth perpetuates the belief that direct DOD funding for manufacturing technology development is inappropriate and that indirect actions, particularly to stimulate increased competition, will be sufficient to assure adequate manufacturing processes. The myth ignores the unique nature of weapon systems and the unusual market in which only one primary buyer exists for products that require years to develop and produce. Although competition for defense contracts is intended to provide the advantages of a free market, the ability of that competition to stimulate manufacturing technology development is limited by several factors:

- Price is negotiated. As the only buyer, DOD exerts a level of control absent in a free market, which increases the contractor's risk and vulnerability.
- The time lag between the decision to pursue the concept of a new weapon system and production is often between 5 and 10 years. It is, therefore, natural that awards of contracts emphasize design capability.
- Uncertainty over winning a production contract is likely to deter a contractor from considering or investing in manufacturing technology during product design.
- Most production contracts have annual competitions or renegotiations, and prices are reduced to reflect reductions in costs.

Many also believe the second myth that process technology automatically follows product development. If that were so, then process development would not require the attention of DOD. However, process technology often must precede or coincide with product development; otherwise a long, difficult effort is required to develop essential and efficient new manufacturing processes to support a weapon system. This second myth also reflects lack of understanding of how new manufacturing technology can permit creation of new product designs and performance features as well as facilitate the production of products already planned.

In fact, the United States is becoming increasingly dependent on foreign suppliers for critical equipment. Change must occur quickly if several existing domestic sources of leading-edge technology are to survive.

The third myth, which stresses measurable cost reduction as the primary goal, manifests itself in two ways. Some in DOD top management support the ManTech program because of its potential to reduce costs, while others question the need for the program when it cannot show demonstrable cost reductions. ManTech program managers, in response to these reactions, have emphasized projects where cost reduction can apparently be measured objectively.

The program's current emphasis on short-term, demonstrable cost reduction is self-defeating. While improvements in quality, lead time, flexibility, and other manufacturing characteristics can often lead to substantial cost reductions, the pursuit of measurable cost savings generally leads to low-payoff projects that address near-term needs.

In addition, despite the continuing emphasis on demonstrable cost savings, cost reduction efforts can rarely be measured accurately. If a new technology is used on a system that has just entered production, there is no baseline against which to measure savings. Even for systems already in production, present cost accounting practices will produce faulty estimates of cost reduction (as described in Appendix B).

The fourth myth, that overhead is always bad, is as pervasive as the first three though it stems from a different set of false assumptions. It reflects a misunderstanding of the difference between overhead rates and overhead accounts--and a fear of both. An overhead rate is the ratio of indirect costs to direct labor costs. As direct labor decreases, the overhead rate

will increase even if the actual indirect costs remain constant. Overhead accounts are a bookkeeping category. Neither the rate nor the account is a measure of efficiency or of total cost.

Acting to reduce overhead limits investments in manufacturing technology in two ways. First, investments that improve manufacturing technology will increase the fraction of total costs that appear in overhead accounts. Second, many advances in manufacturing technology are directed at reducing direct labor and may increase some indirect costs such as computer programming or maintenance. In both cases, the overhead rate will rise. Thus, a company that is successfully implementing advanced manufacturing technology is likely to increase its overhead rates and overhead expenditures--although the total cost of production can be expected to decrease even while lead times, quality, and yields improve. A goal to control the increase in overhead rates will surely lead to less efficient and less effective manufacturing processes.

Elevating the Status of the Program

The lack of understanding of manufacturing technology is evident not only in the absence of policy direction from DOD or in the prevalence of manufacturing technology myths, but also in the organizational location of the ManTech program. The ManTech program has been located far down in the hierarchies of all three services.

Some of the individuals interviewed attribute the limited use of the ManTech program to its small size, especially relative to many other programs--such as weapon system procurement budgets. Even at the program's highest level of funding in 1982, only $204 million was appropriated for all three services, an amount representing just over 0.1 percent of the defense procurement budget of $150 billion. Nevertheless, ManTech's importance far exceeds its share of the budget because of its enormous leverage and potential to strengthen the competitiveness of the U.S. industrial base.

CONCLUSION

Much of the ManTech program of the past decade has had only a modest impact. Within the program, however, there have been highly successful examples where related sets of

technically challenging projects were aimed to solve fundamental problems in producing the next generation of weapon systems. Examples include composites, integrated computer-aided manufacturing, and electronic materials. If the entire program were managed to solve challenging, fundamental manufacturing technology problems, the overall effect of the program's modest expenditures would have been enormous.

The actual impact of the program, however, was limited by the lack of strategic guidance from the Department of Defense. Several groundless but widely held myths have been used to support the erroneous belief that manufacturing technology was either an unimportant or an inappropriate concern of DOD. Continued acceptance of these myths could be devastating for the next generation of weapon systems. DOD must provide direct support for manufacturing technology development if the defense industrial base is to produce high quality, reliable weapon systems in a timely, efficient manner.

3 STRATEGY AND ORGANIZATION

Although DOD has never developed an explicit peacetime strategic manufacturing plan, its implicit strategy has been consistently to neglect manufacturing equipment and process technology. This neglect has:

- forced important manufacturing capabilities to leave the United States almost entirely,
- caused weapon systems to increase in price while similar commercial products have decreased in price, and
- allowed the defense industrial base to erode.

WHAT A MANUFACTURING STRATEGY ENTAILS

We are calling, therefore, for the formulation of an explicit manufacturing strategy for DOD. The strategy should acknowledge DOD's pivotal role in the health of the manufacturing base, take advantage of DOD's commanding share of total U.S. expenditures on durable goods, convey to defense contractors the importance of manufacturing technology to DOD, and remove some of the costly uncertainty facing defense contractors. The strategy must encompass not only the prime contractors and internal DOD organization, but also the myriad suppliers and vendors to the prime contractors.

Among the questions that the strategy should address are:

1. How much of the defense budget should be devoted to ensuring the availability of enabling process technologies on a timely basis?
2. Which process technologies will be critical to cost-effectively producing the next generation of weapons?

3. Which process technologies are in danger of losing needed domestic sources?

The Secretary of Defense should require the development of a strategy that addresses these issues. The actual formulation of the strategy probably needs to be done by the Secretaries of the Army, Navy, Air Force, and Defense, or by their Under Secretaries, to encompass the issues with sufficient breadth and authority. The officials responsible for formulating the strategy need not have detailed knowledge of manufacturing processes. Rather, they need to know what industries, materials, weapon systems, and performance requirements will be critical to DOD in the next 5 to 10 years. Technical advisers can provide the bridge between those factors and manufacturing. The senior officials, however, should establish the priorities.

Once the strategy identifies the technologies that are essential for future weapon systems, the ManTech program managers, in concert with other experts including contractors, can develop approaches for addressing the advances needed in manufacturing technology. The program budget can then reflect clearly the effort needed to achieve progress in each area.

Broad procurement issues that affect the development and use of manufacturing technology should also be part of the strategy. Examples include treatment of overhead rates and strategies to consider manufacturability early in the design process. More specific procurement issues are also important. For example, the current time lag between the idea for a project and its funding--often 2 to 3 years--is far too great. DOD could benefit from tailoring specific contracting procedures for investment in innovative but risky process technologies, so that the investment is made in a timely manner.

ORGANIZATIONAL RELATIONSHIPS

In the past, the services have created essentially separate ManTech programs.[1] The ManTech office at the Air Force Materials Laboratory has provided centralized control, redirected resources when needed, coordinated related projects, and defined future needs. It identifies the projects for which contractors compete. In contrast, the Army did not develop projects internally. It relied on proposals from contractors for specific ManTech

projects. Also, the Army program was dispersed throughout many major subordinate commands, each of which received funding based on historical levels rather than future needs. Similarly, until recently, the Navy program was dispersed among commands and laboratories and still has a small, relatively weak, non-technical central office.

These varied experiences provide characteristics to emulate as well as some to avoid. Management structure and responsibilities should reflect the following principles:

- communication among the Office of the Secretary of Defense (OSD) and the services in defining priorities so that projects respond to defense needs;
- some centralized control in OSD to coordinate the services in a unified program;
- since the services can best identify manufacturing improvements to support mission objectives and are more closely involved in defining product requirements, they retain control of project definition and management;
- centralized control of the program within each service to provide unity and strong program management direction;
- in consonance with the Packard Commission's recommendations for decentralized management,[2] the military services define and manage individual ManTech projects; and
- the services work with contractors and vendors, particularly in designing projects, to determine the state of the art and future needs; projects should reflect not only the priorities but also the contractors' economic and technological needs and capabilities.

The specific application of these principles in an actual program is the responsibility of the Secretary of Defense. One reasonable approach to ManTech program management would include the following:

- The Secretary of Defense establishes a central manufacturing policy office in OSD, at a level high enough to have the ability and authority to provide substantive direction to the services and to control budget resources.
- The OSD policy office and the services expand on the strategic priorities by developing broad, cohesive technical approaches to achieve the established goals.
- The OSD policy office assesses the effectiveness of the overall program but not of individual projects.

The office develops a "benchmarking" system to monitor available and developing process technologies here and abroad in areas important to weapon systems. The assessment ensures that proposed projects are in concert with defense priorities and the objectives laid out in Chapter 4.

- Each service establishes a central program office for project management.
- To provide a high level of manufacturing expertise and information on the capability and needs of defense contractors, OSD establishes a civilian advisory function.

AN EXAMPLE

As a specific example of the process we recommend, consider a program to explore the use of composite materials for aircraft. OSD and the services identify composites as having high strength-to-weight ratios, eluding detection by radar, and being noncorrosive, traits that are needed in a variety of future weapon systems.

Working with contractors, ManTech program managers determine that producing complex, large, or numerous composite structures is either impossible with current technology or extremely expensive. Specific technological objectives are defined. The needs are further clarified in terms such as "reduce rejects by 50 percent on all composite structures" and "determine nonautoclave methods for curing large composite structures." The ManTech program, in response, focuses a major portion of its funding on meeting these production specifications for composites.

Individual services then take the lead on specific problem areas. For example, the Air Force might focus on small complex structures, the Navy on large structures, and the Army on high-volume production. Projects would be designed to meet the specific technological objectives that, as a group, will help meet a strategic goal. Other DOD initiatives could then be used to ensure that successful projects are incorporated into production of the next generation of weapon systems.

CONCLUSION

A manufacturing strategy needs to be set by the Secretary of Defense. Direct funding of manufacturing

technology development will be one part of such a strategy. Priorities established by the Secretary of Defense for the ManTech program will enable ManTech program managers to support the development of process technologies to produce future weapon systems. In this way, the ManTech program can play a major role in improving the manufacturing capabilities of the defense industrial base.

NOTES

1. The Statement of Principles for Department of Defense Manufacturing Technology Program, dated March 14, 1980, provides guidance that the services follow to varying degrees. In the matter of centralization, for example, the principle is that "[e]ach Service will provide strong central program management . . . ." We agree with this principle but find that the Air Force was most successful in fulfilling it.

2. Interim Report to the President by the President's Blue Ribbon Commission on Defense Management, 1986.

4 SELECTING PROJECTS AND EVALUATING THE MANTECH PROGRAM

FUNDAMENTAL PROGRAM MISSION

As it currently operates, the ManTech program's mission, implicit and stated, is too diverse to offer a useful basis for managing and evaluating the program. If the program is to contribute meaningfully to strengthening the defense industrial base, it must have an unambiguous mission that derives from DOD's needs. We recommend that:

> The mission of the new ManTech program is to fund the enabling manufacturing technology developments required for the efficient, effective production of future weapon systems that support DOD's strategic plans.

OVERALL PROGRAM CHARACTERISTICS

The mission will require a new set of criteria for the selection and design of ManTech projects. The first step, as described in the previous chapter, is for high-level DOD officials to identify the technologies that are critical for the next generation of weapon systems. The program managers can then select projects aimed at meeting those needs. When these decisions have been made and new processes developed, future generations of weapon systems can be designed to incorporate the new equipment and process technologies.

In consonance with the new mission and to improve the program's effectiveness, each ManTech project should have four characteristics:

1. The project focuses on innovative, emerging technologies.

This characteristic should enable all technically successful ManTech projects to achieve the major impact that only a few have had in the past. All ManTech projects will be sufficiently forward-looking to have some risk of failure; groups of projects will support the exploration of process technologies that promise significant advances in manufacturability or product performance. Such support is not now likely to come from either individual companies or weapon system program budgets.

2. The technology to be developed has broad, general applicability.

Diffusing newly developed technologies is a key benefit of direct DOD funding of innovative process development because DOD generally retains the license to military applications of such developments. Funding generic process developments will improve chances for technology transfer and increase the leverage of ManTech funds. Technologies developed with ManTech funding should be potentially useful to many companies, services, weapon systems, and products. ManTech funding to develop a technology for only one supplier is less appropriate.

3. The project funds a technology that is not being adequately developed with private sector funding.

Direct funding should support technology development that would not be achieved by other sources in a timely manner. Companies are unlikely to fund development efforts adequately if the technical risk is high and the likelihood of gaining the benefits is low. ManTech projects should initiate or accelerate exploration of critical, underexploited technologies and hasten dissemination of results.

4. The technology funded is needed to establish, reestablish, or preserve domestic capability in a manufacturing process critical to the defense industrial base.

The ManTech program's support of promising, new manufacturing technologies should strengthen or restore critical process capabilities whose decline is leading

to reliance on sources outside the United States. The program will focus on technologies that are used by more than one industry, company, or product, rather than on those specific to weapon systems.

ManTech's new mission and the four basic characteristics of a new program should cause the U.S. defense industrial base to undertake innovative, strategically significant manufacturing technology efforts that it would not otherwise undertake.

It is worth noting that the Statement of Principles for DOD Manufacturing Technology Program (March 14, 1980) also lists four characteristics for "project selectivity." Two are similar to numbers 2 and 3 above. The other two--that technical feasibility has already been demonstrated, and that results can be delivered in time to meet a well-defined DOD requirement--are inconsistent with our recommendations. The two inconsistent selection characteristics of the existing program reinforce the tendency toward short-term cost reduction rather than stimulating the major advances in process technology we expect the new program to achieve.

INDIVIDUAL PROJECT OBJECTIVES

Individual projects in the new ManTech program should be designed to improve the manufacturability of future generations of DOD equipment and systems. In practical terms, projects should contribute to one or more of the following objectives:

- provide new process capability,
- improve quality, reliability, or durability,
- reduce lead times,
- reduce procurement costs,
- enhance manufacturing flexibility,
- reduce adverse consequences of production (such as accidents, pollution, or toxicity), and
- establish more productive management systems.

No single project is likely to meet all seven of these objectives. The most challenging will aim to contribute to several, as did the superlative projects of the current program described in Chapter 2.

These objectives are important both for selecting among proposed ManTech projects and for monitoring the progress

of existing projects. Chart 4.1 describes the characteristics of each objective.

It is possible to rationalize that any project meets at least one of these objectives. Therefore, coherent informed judgment of whether a project offers sufficient gain is essential to a sound program.

EVALUATION CRITERIA

Meaningful evaluation of the new ManTech program must be tied to its fundamental mission. After a group of related projects is completed, the overall success of that area should be evaluated, rather than the success of individual projects. It is the nature of high-risk projects that many of them will fail, at least initially. A number of factors external to the program may inhibit use of project findings. The effects of individual projects may be impossible to ascertain or measure. Further, it takes time to define, develop, and implement new technology, and program evaluations often take place before sufficient time has passed for results to be implemented. For all these reasons, in-depth tracking of the results of individual projects is not an affordable, appropriate, or even feasible basis for evaluating the ManTech program.

The new ManTech program, instead, should be judged successful if:

- it has funded a critical mass of projects that address the manufacturing technologies selected as strategically significant by DOD, and
- it has had sufficient technical success to provide the means for more effective and efficient manufacture of DOD weapon systems.

Chart 4.1

OBJECTIVES FOR MANUFACTURING TECHNOLOGY PROJECTS
(Each project should aim to achieve one or more of these.)

1. New Process Capability: ManTech funding would be used to make new materials or new product technologies more affordable and available for use in new systems. An example is the automation of composite lay-up for large structures.

2. Improved Quality, Reliability, and Durability: ManTech projects would be targeted at technologies that would make high quality, reliable products. Examples include increasing yield of chip manufacture and developing manufacturing technologies that can increase the mean time between failure of circuit boards.

3. Reduced Lead Times: Funding would be used to reduce the time between major points of production, such as transfer time between design and manufacturing, and production start-up times.

4. Reduced Procurement Costs: Improvements in other criteria will often lead to lower costs, but it is also possible for a project to reduce production costs by such direct means as automating a time-consuming manual process.

5. Enhanced Manufacturing Flexibility: ManTech projects would be aimed at increasing flexibility over short, medium, and long time periods. Examples include reducing set-up times, facilitating volume and schedule changes, and producing multiple products on the same equipment.

6. Avoidance of Adverse Side Effects: Manufacturing Technology projects would be aimed at reducing two types of adverse side effects--hazardous working conditions and unwanted by-products.

7. Improved Management Systems: Projects would be targeted at improving the management of production by such means as just-in-time production systems, and automated storage and transfer of product designs.

5 CONCLUSION

The problems of the U.S. defense industrial base are reflected in long lead times to procure weapon systems, high costs, uncertain quality, and more frequent procurement of components from other countries. These problems happened in part because manufacturing process development has been allowed to lag product development for weapon systems.

The ManTech program has had some success in promoting the development of manufacturing technology to produce weapon systems. If DOD had given investment in innovative manufacturing technology high priority and more strategic direction, the program could have accomplished more.

We recommend a new ManTech program that directly funds investment in a few innovative manufacturing technologies needed for the next generation of weapon systems. The Secretaries of the Army, Navy, Air Force, and Defense need to establish priorities for future weapon systems. ManTech program managers in the services can then translate those priorities into specific groups of projects. We believe they have proven their ability to do so.

ManTech projects should be selected to be innovative, generic, not adequately funded by the private sector, and critical to the capabilities of the defense industrial base. Evaluation of the ManTech program should reflect the limits in measurement abilities and in the standard accounting system. The program should be judged successful if it has (1) funded a critical mass of projects to develop the technologies needed for future weapon systems and (2) achieved sufficient technical success to advance the state of the art.

Appendix A
ANALYSIS OF MANUFACTURING TECHNOLOGY PROJECTS

The committee supplemented its interviews with an in-depth analysis of 238 Manufacturing Technology projects. The 238 projects are all those that (1) had total ManTech funding of at least $1 million and (2) received some ManTech funding during 1985 or 1986. They comprise 40 percent of the projects during that period.

The services provided summaries of the objectives and approaches of all of their ManTech projects. We coded each project according to its characteristics in four areas:

1. Purpose: What was the purpose--i.e., the anticipated benefits--of the project as stated in its proposal?
2. Material: What materials (e.g., steel, composites) were involved?
3. Breadth: What was the degree of applicability to various processes, materials, facilities, or products?
4. Technology: To what manufacturing technology was the project directed (e.g., forming, welding, inspection)?

The tabulation of the answers to these questions for the 238 projects forms the basis for the committee's judgments concerning:

- the strategy that was implicit in the selection of projects,
- the priorities in the program, and
- differences in the program across the services.

The projects analyzed by service are shown in the chart on the following page. The value of these projects, more than $800 million, is equivalent to 4 years of the program's total funding at its highest level of $200 million.

Service	Total Projects Funded	Number Analyzed	Percentage of Projects Analyzed	Total Cost of Projects Analyzed
Army	332	111	33	$328 million
Navy	125	35	28	81 million
Air Force	129	92	71	402 million
Total	586	238	40	$811 million

All of these projects were active during 1985 or 1986. They represent, however, a spectrum of program initiatives. Some began in the late 1970s and others commenced as late as 1986. This analysis, therefore, reflects decisions made over the past decade.

SUMMARY OF RESULTS

The results of the analysis supported the message that had emerged throughout many interviews: the ManTech program lacks an overall strategy. The services appear to have programs quite independent of each other. Within the services, the Air Force has the only program with a discernible pattern of projects toward a technical or managerial objective. The Air Force also has the program supporting the largest percentage of large projects.

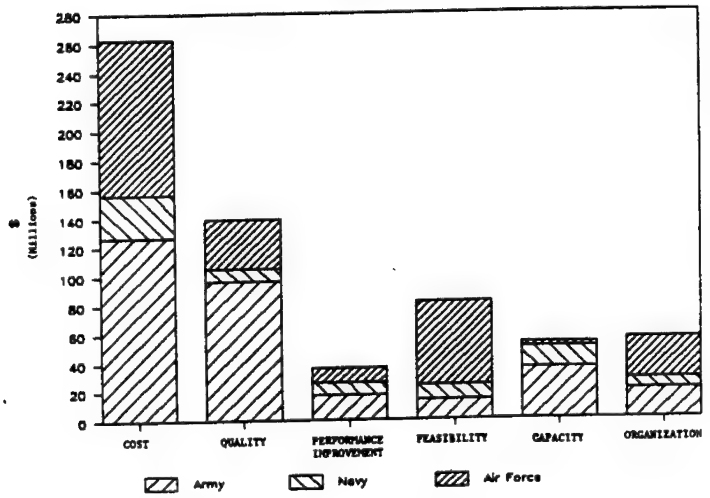
The characteristics of the projects also suggest that individual efforts are likely to be limited in their impact. Many projects replicate existing technology and are for unique or limited applications. Few of the projects are likely to stimulate contractors to invest in follow-on work, thus limiting the leverage of ManTech funds.

While the program's impact is limited, in part, by the characteristics of the chosen projects, it is also limited by current program regulations. The vast majority of ManTech funds is used to determine if existing technology can be applied in a production environment. ManTech funds are prohibited for process technology that has not been proven feasible in a laboratory. Because DOD has no research program for initial development of manufacturing technology, the ManTech program is limited to research that has been completed. It cannot direct research itself.

RESULTS BY CRITERION AND SERVICE

Purpose: The two most commonly cited purposes for projects in all three services were reducing costs and improving quality. More than 40 percent of all projects and 30 percent of funds were for projects citing cost reduction as the primary purpose; many more mentioned it as a secondary objective. Improving performance and increasing capacity were the least cited objectives, as Chart A.1 shows.

Chart A.1



The frequent listing of cost reduction in approved project requests suggests either that actual cost reduction projects are more likely to be funded or that packaging projects in cost reduction terms is a good strategy for companies seeking ManTech funds. In either case, the projects that are selected, for the most part, are rarely high risk, long term, or significant technical advances.

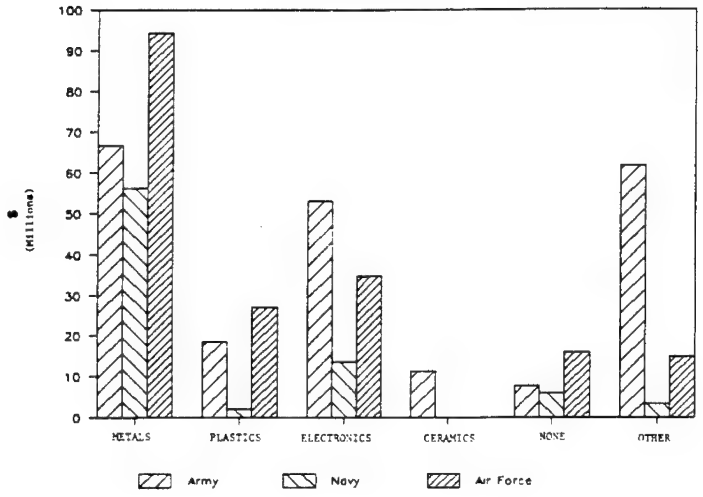
The emphasis on quality improvement appears to be commendable. Unfortunately, many of the projects that cite quality as the primary objective are directed at improving the inspection process, rather than at reducing the need for inspection. While certain inspection processes could clearly benefit from ManTech projects, projects that aim to eliminate defects, and thereby

eliminate rework and inspection, would have a greater impact on the overall production system.

Materials: Approximately 36 percent of the projects were aimed at processes affecting metals as opposed to other materials such as composites, plastics, or ceramics (see Chart A.2). Further, much of that funding was devoted to steel. Within the services, the Navy expended 63 percent of its funds on metals, compared to the Army's 20 percent.

Although some projects are necessary for developing processes to handle complex shapes or new alloys, the emphasis on metals--especially steel--seems inconsistent with the needs of future weapon systems. Much less work in ceramics, electronics materials, infrared sensors, and plastics has been funded than seems warranted.

Chart A.2

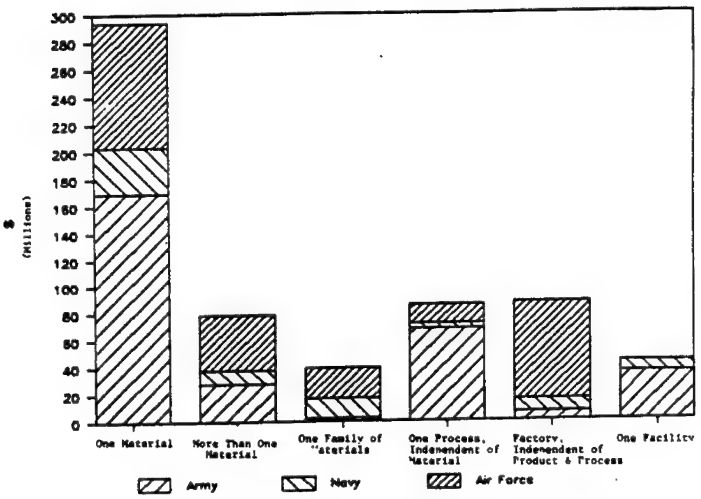


In some instances, work on traditional materials may be appropriate because a vast quantity of a product is required. Many of these projects, however, lack the breadth and degree of risk that are necessary to achieve significant results. Particularly in the Army, the expenditures for munitions are largely straightforward production engineering, which will improve safety and efficiency but have limited applicability.

Breadth: The wide variety of technologies included in the ManTech program testifies to the number and diversity of opportunities and needs for new process technology. It is this enormous breadth that requires choices and careful structuring of projects so that limited funds are not dissipated across many technologies. Such choices appear not to have been made, and projects, in general, have been designed to narrow the focus rather than broaden it.

In all of the services, the preponderance of projects have narrow technical objectives (see Chart A.3). If successful, they will help only a single product, frequently only a single step in the production process, and often only a single facility or weapon system.

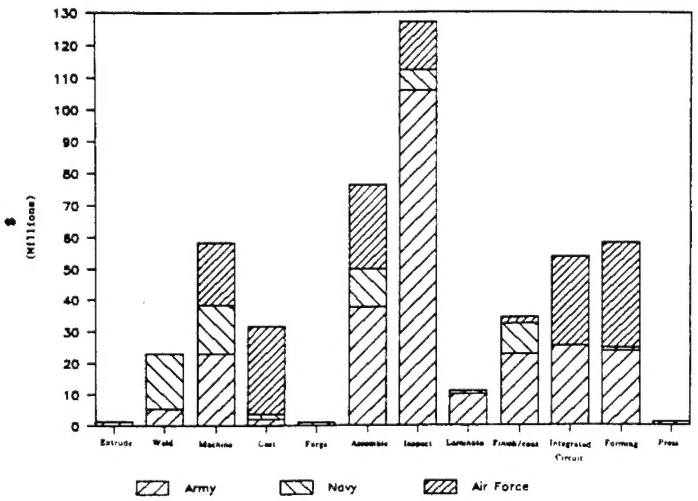
Chart A.3



In contrast, the Air Force has funded several groups of projects that relate to overall thrust areas. The projects are concerned with generic issues, such as flexible machining of short runs of spare parts or original equipment, and offer wide applicability and significant results.

Technology: The manufacture of weapon systems involves a wide variety of production processes, such as welding, forming, machining, casting, and assembly. In this area, the projects differ markedly across services; each service has concentrated on different processes (see Chart A.4).

Chart A.4



- The Army has focused over 30 percent of its funds on inspection. While improving inspection is important, improving other aspects of the production process to reduce the need for inspection would have greater benefits.
- The Air Force has equally supported projects in casting, assembly, production of integrated circuits, and forming.
- The Navy has also focused on several production processes, such as welding, machining, and assembly.

Extrusion, forging, and lamination are examples of production processes that receive little support from any of the services.

Appendix B
PROBLEMS IN MEASURING COST REDUCTION: AN EXAMPLE

Current criteria used to evaluate the Manufacturing Technology program emphasize cost reduction. To demonstrate that projects have been successful, ManTech program managers have attempted to measure cost reductions that are attributed to investments by contractors in the results of ManTech projects. Many factors limit the utility of this approach:

- The program has no control over whether contractors decide to invest in equipment or processes developed under the program.
- When investments are made, they are difficult to link to changes in price, since price can change for many reasons.
- For new weapon systems, no cost or price baseline exists, so that showing the effect of one investment is an estimate at best.
- Several years may elapse between the end of a project and an investment that uses the technology developed in the project.

Cost reduction is also difficult to measure, however, even when a baseline exists and changes in direct costs can be accurately measured. Once indirect costs are calculated, as they must be if changes to price are to be measured, then the system produces major inaccuracies.

The following example illustrates the errors that arise from using existing direct-labor-based cost accounting systems to measure the cost reduction improvements resulting from a ManTech project.

A plant produces several products only for DOD. The prices for the products are negotiated on the basis of direct and indirect costs. The contractor has decided to

invest in new technology, based on the results of a ManTech project, that will improve part of its production process, but for only one product.

Based on a normal workload, the plant has 160 workers billing 320,000 direct labor hours (DLH) per year to the defense contracts. The investment that uses the results of the ManTech project will affect the single largest DOD contract in the plant. It employs 100 of these workers, billing 200,000 DLH per year. The plant's overhead costs are $28,800,000 per year.

Following procedures established by the Cost Accounting Standards Board, the indirect costs are allocated to the various DOD projects via a burden rate on direct labor. Currently, this rate is $90 per hour ($28,800/320); the full cost of a direct labor hour, including salary and fringes is $20 per hour. Virtually all of the overhead is considered fixed; it does not vary in the short run with fluctuations in the plant's work load. (Material costs in this example can be ignored as they will be assumed unchanged by the ManTech investment.)

The plant invests $1 million to improve a production process and significantly reduce labor costs. The new technology produces a 16 percent reduction in the labor hours required to build the designated defense product.

At the end of the year, consultants to the ManTech program review the project to assess the benefit-cost ratio. The 16 percent labor hour reduction meant that instead of 200,000 hours being billed to the project, only 168,000 hours were billed. The savings of 32,000 DLH is valued at the $20 direct labor hour rate plus the $90 burden rate on the direct labor producing a total savings of $3.52 million (32,000 x [20 + 90]). Thus, the ManTech program had a benefit-cost ratio in excess of 3.5 to 1, a success story.

What has not been assessed, however, is the change in the burden rate caused by fewer direct labor hours. Therefore, when DOD auditors attempt to validate the amount, they find a somewhat different situation. The plant now has an overhead burden rate of $100 per hour, not the $90 assumed in the budget projection. This figure is computed as the ratio of the factory overhead costs of $28.8 million divided by the 288,000 actual labor hours worked (168,000 on the project receiving ManTech funds and 120,000 on all the other projects). The auditors now compute a different estimate for the savings from the ManTech funding:

Estimated costs before funding:	
200,000 DLH @ ($20 + $90)	= $22,000,000
Actual costs after funding:	
168,000 DLH @ ($20 + $100)	= 20,160,000
"Audited" savings	$ 1,840,000

Thus, the auditors find that the "true" savings were $1.84 million--only half the amount claimed by the ManTech consultants. But fortunately, the savings still exceeded the ManTech investment of $1 million. Of course, the auditors might also note that the defense products being produced in the remainder of the plant are now more expensive than had been expected. The higher cost is due to the jump in the overhead burden rate from $90 to $100 per hour.

In fact, neither the consultant's savings estimate of $3.54 million nor the auditor's estimate of $1.84 million is valid. The only real savings from the process-improving investment arises from the reduction in direct labor. Assuming that the $20 per hour rate is valid for measuring the savings from reducing each hour of direct labor worked, the total savings from the ManTech investment is $640,000 (32,000 hours saved x $20 DLH).

While the setting has clearly been simplified to make a point, it should be obvious that cost savings computed using existing cost accounting systems cannot possibly provide a valid estimate of the savings in process efficiency from ManTech investments.